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Networks at the science-policy-interface: Challenges, opportunities and the viability of the 'network-of-networks' approach

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ABSTRACT

An approach that has been suggested as potentially addressing the challenges of science-policy-interfaces (SPIs) is the mobilization of existing networks through a 'network-of-networks' (NoN) approach. This paper shares empirical findings from a mixed-method study, combining qualitative and quantitative data, that critically evaluates the 'network-of-networks' approach for SPIs. To establish whether and how a NoN can help existing networks act more effectively at the boundary of science and policy, we use the Eklipse Mechanism as a key example. We analyse the major characteristics of networks active in biodiversity-focused science-policy interactions, the potential roles and types of engagement of participants, and the major challenges faced by networks and individuals when acting at the boundaries of science and policy. Results suggest that the more diverse the actors involved, the more effective the SPI. While a formalized EU-level SPI for biodiversity is welcomed by most respondents, willingness and actual potential to contribute to such an entity differed amongst networks, highlighting that contributions to SPIs are highly dependent on individual and organizational capacities. The challenges faced by individuals and networks range from limited resources to effective communication and achieving meaningful impact even if the institutional context is unrewarding. To make a 'network-of-networks' model fully operational requires meeting the capacity building needs of networks, providing institutional support, and creating room for wider engagement.

1. Introduction

A number of initiatives exist globally to improve the use of scientific and other knowledge forms in policy decisions. These occur across different sectors, including forestry (e.g. the Global Forest Expert Panel - GFEP[1]), agriculture (e.g. IPES-Food[2]), and environmental sectors,

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[1] The Global Forest Expert Panels (GFEP) Programme aims to provide scientific expertise to governments and intergovernmental processes related to forests through an effective communication mechanism working at the regional and global level.

[2] IPES-Food – the International Panel of Experts on Sustainable Food Systems – is an independent panel of experts from multiple disciplines and knowledge systems to promote the transition to sustainable food systems by providing system-wide and independent knowledge to decision-makers.

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including climate change (e.g. the Intergovernmental Platform of Climate Change - IPCC[3]), biodiversity and ecosystem services (e.g. the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services - IPBES[4]), and sustainable development (e.g. Future Earth[5]). Nevertheless, many such initiatives are facing challenges in terms of effective communication, mobilization of diverse knowledge forms, and acting upon research findings, mainly because science-policy interactions continue to be conceptualised as linear processes (Toomey et al., 2017; Young et al., 2014) where science is assumed to provide clear, relevant, credible, legitimate, and actionable knowledge on which decision makers will pursue decisions (O'Sullivan et al., 2018). When science-policy interfaces (SPIs) are managed as collaborative, non-linear processes, scientists, decision makers, and representatives of the general public are engaged in an iterative process and negotiate together what information is needed and what kind of evidence is relevant in the given situation (Heink et al., 2015; Sarkki et al., 2015). While this non-linear approach to SPIs can be considered as a way towards improved implementation and behavioral change (Tinch et al., 2018), it also creates a space for debate over conflicting beliefs, values and interests (Toomey et al., 2017).

SPIs show a large diversity in terms of organization and governance, but two main types stand out: the network approach and the platform approach (Görg et al., 2016; Sarkki et al., 2015) (Fig. 1). The network approach suggests an open and loosely coupled model, complementary to existing structures, which engages individual network members on a voluntary (self-registered) basis. OPPLA, a European knowledge repository on natural capital, ecosystem services and biodiversity, operates such a network of organizations and individuals from diverse backgrounds based on voluntary and flexible collaboration. The platform approach embodies a more tightly coupled organizational solution, a membership at the organizational level, which needs a stronger governance structure, and while it guarantees rights to member organizations, also imposes requirements on them (Görg et al., 2016). Examples of a platform approach include global intergovernmental organizations, such as IPBES and IPCC, and international (regional) platforms, such as ALTER-Net (a network of European research institutes collaborating on biodiversity related topics). As the transition between the network and the platform approach is gradual, diverse combinations (hybrids) can be purposefully designed to create synergies and build a more robust and trustful interface (KNEU Team, 2014).

Based on a participatory dialogue engaging various actors of the SPI, previous EU projects, such as SPIRAL and KNEU, provided recommendations on how such hybrid institutional arrangements could be set up and run with increased transparency and ethical standards (KNEU Team, 2014; Young et al., 2013). Three basic functions, and some more specific roles within these functions, were identified as needing to be fulfilled to this end (Nesshöver et al., 2016; KNEU Team, 2014). The first function is the synthesis of available knowledge, which can be operationalized by providing thematic and methodological expertise, providing research tools and infrastructure, and ensuring access to scientific databases and up-to-date information. The second function is the development of a common research strategy, which includes foresight and evaluation activities, and makes the SPI capable of acting as a think tank, when necessary. The third function encompasses capacity development, networking and international collaboration, and can be achieved through communication, knowledge sharing, capacity building and social engagement activities.

The networking and capacity building function of an SPI can ensure that diverse knowledge holders are connected and collaborate with each other at the interface to effectively resolve the policy problem (Tremblay et al., 2016). A recent systematic review (Matsumoto et al., 2020) found that capacity building is a crucial element of effective and lasting collaborations between science and policy. From a capacity development approach, the key capacities needed to increase the adaptive ability of organizations and the wider society include financial and human resources, governance and leadership capacities, knowledge integration and learning capacities, social networking skills, and motivational capacities (see e.g. Kuhlicke et al., 2011; Gupta et al., 2010). There are already communities of interest dealing with biodiversity and ecosystem services, and developing their skills and capacities is possible through improved networking and shared best practices. Organizing a 'network-of-networks' (NoN) can help to access up-to-date knowledge and reduce redundancies, and at the same time improve the policy outreach of existing networks (Carmen et al., 2015). Empirical evidence is needed, however, on how a 'network-of-networks' can actively support its members and contribute to the functioning of the SPI.

'Network-of-networks' (NoN) - or more generally the mutual interdependence of existing networks - is extensively studied and modelled in physics and mathematics (Gao et al., 2014; Kenett et al., 2015). Several studies suggest that the higher the number of networks within a NoN, the smaller its robustness (Gao et al., 2011; Havlin et al., 2015), i.e. if more networks are organized in an interdependent system, there is an increasing chance of a failure within one network which may have cascading effects on the others. A key consideration is whether these findings also apply to a NoN approach in the context of the SPI.

Developing a NoN that facilitates the cooperation of diverse actors and disciplines to fill knowledge and capacity gaps would appear central to the effectiveness of SPIs, but also challenging in terms of motivation, engagement, and organization. This paper therefore critically evaluates the 'network-of-networks' approach for SPIs through its focal question: *Can a NoN approach help existing networks act more effectively at the SPI, and if so how?* To answer this question we look at networks, currently active at the SPI, from three different angles as listed below, and then discuss networks' motivations to join a NoN with a particular focus on capacity building opportunities. The three more specific questions addressed in the paper are the following:

1 What are the main characteristics of existing networks which are active at the SPI?
2 What contributions are needed and by whom in order to build a NoN for a well-functioning SPI?
3 What are the major challenges that hinder the active participation of networks at the SPI?

The paper shares empirical findings from a mixed-method study carried out as part of the Eklipse project, which has developed a mechanism at the European scale to gather evidence relevant to decision-making by establishing dialogue between science, policy and society. To achieve its core objective, Eklipse promotes the engagement of networks whose knowledge has a key potential impact on biodiversity, ecosystem services and related environmental challenges in a 'network-of-networks' (Watt et al., 2018). For the purposes of this study, 'networks' are defined in a broad and inclusive way, including different kinds of 'organized exchange' such as informal thematic networks, formal networks of institutions, learned societies, NGOs, and projects. The NoN is understood here as an open platform for engagement, where member networks are encouraged to take on different roles and responsibilities according to their resources, and can enjoy the benefits of improved information flow, more direct links with policy making, and various opportunities for capacity development.

[3] IPCC is a UN body established in 1988 to feed synthesised scientific knowledge on climate change, its implications and the management of potential future risks into policy processes.

[4] IPBES is an independent intergovernmental body established in 2012 by national states. It aims to strengthen the science-policy interaction concerning biodiversity and ecosystem services to ensure the more effective conservation and sustainable use of nature.

[5] Future Earth, announced in 2012 at the UN Conference on Sustainable Development, is a global network of researchers and innovators which provide knowledge to underpin evidence-based policies for sustainable transformations.

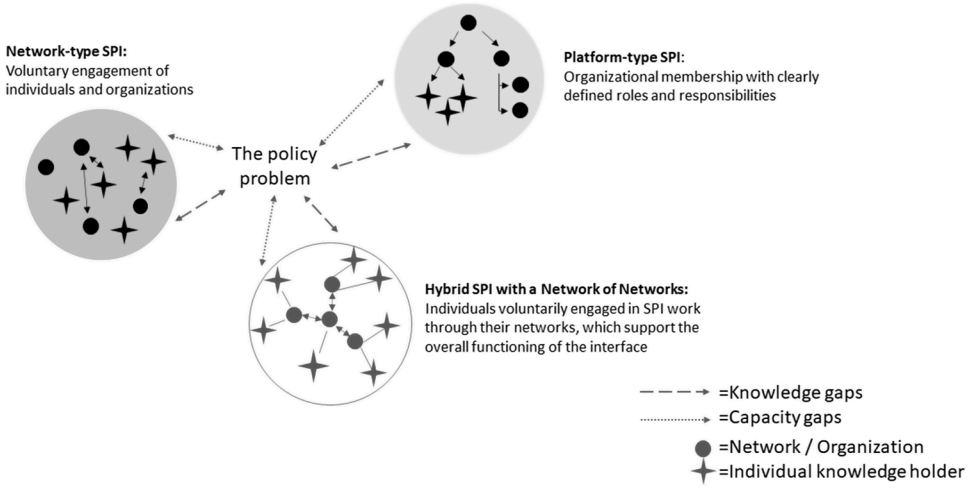

Fig. 1. Different approaches to engage diverse knowledge holders in science-policy interfaces (SPI).
Three different arrangements of networks/organizations (signed with dots) and individuals (signed with stars), as well as the links between them, are shown in the picture: the network, the platform and the hybrid type of SPIs. Dotted arrows indicate gaps in capacities and dashed arrows indicate gaps in knowledge, both of which can act as barriers to tackling a policy problem at the SPI. Source: own edition.

The paper is structured into four main sections. A detailed methodological description outlines the qualitative and quantitative approaches applied. This is followed by a section reporting on our major findings, including the characterisation of networks active in science-policy interactions, the different patterns of collaboration and engagement along the SPI, and the major challenges identified when working at the SPI. The discussion provides deeper insights into the motivations of networks to join a NoN and identifies capacity building options which could result in a more robust and viable network-oriented SPI. Some final remarks on the potential for a NoN approach in SPIs are discussed in our conclusions.

2. Data and method

A mixed-method and iterative research strategy was applied (Fig. 2). The evolution of the research strategy is described below, while Appendix A introduces the questionnaires and the interview guideline used in the different phases.

In the pilot phase we developed a detailed online survey including both open-ended and single/multiple choice questions (Appendix A.1), and invited network participants to fill the survey online, using the UNIPARK platform. Feedback from respondents indicated that the full questionnaire was too long and some of the questions were difficult to answer online. Therefore we decided to run a face-to-face pilot interview with the same questions to check their ability to provide comprehensive data if asked in a face-to-face situation. Based on the pilot, we split up the initial questionnaire and developed two separate research strands. Most closed questions were grouped into a short online survey to investigate how individuals perceive SPI engagement and associated challenges (phase 2 in Fig. 2, Appendix A.2). Open-ended questions were complemented and combined with two close-ended ones in a semi-structured interview guideline to uncover the key characteristics and engagement strategies of, and challenges faced by, networks actively participating at the SPI (phase 3 in Fig. 2, Appendix A.3). In order not to lose data collected earlier, and because questions highly overlapped, online and face-to-face responses gathered in the pilot phase were analysed together with the semi-structured interviews from the third phase. The methodological approach to sampling, data collection and analysis of the survey and the interviewing is discussed in more detail in the following two sections, respectively.

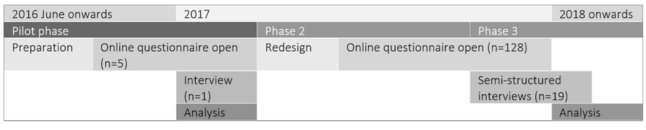

Fig. 2. Research design and timeline.

2.1. Online survey

The online survey included 9 content-specific and 2 background questions (Annex A.2) to discover individual expectations and experiences about SPI activities. Content-specific questions (both open- and close-ended) focused around three topics: 1) whom to involve, how to interact, and which roles to take at the SPI (Q1, Q3, Q4 in the questionnaire, responding to research question no.2.), 2) gaps of knowledge and capacity, and ways to build capacities and effectively communicate at the SPI (Q2, Q6, Q7, Q8 in the questionnaire, responding to research question no.3.), and 3) general expectations towards Eklipse and any other comments and suggestions to share (Q5, Q9). Background questions asked about the network represented by the respondent (open-ended question) and the sectoral background of the respondent (science, policy or civil society).

Questionnaires were available online via the UNIPARK platform (https://www.unipark.com/en/), accessible from various browsers without authentication (i.e. invitation or password). Cookies were used to avoid duplicating responses by the same respondent, but IP addresses were not stored. Conferences, training events and workshops (e.g. AlterNET 2017 conference, ESEE 2017 conference and summer school, SCB Europe section 2017 summer school) were used to advertise the survey and invite people to participate. In addition, the questionnaire was announced through the general Eklipse communication channels and invitations were sent out through personalized emails to relevant networks.

Between May and December 2017, the survey was accessed 432 times, 128 respondents started to answer the questionnaire and 62 respondents completed it (completion rate being 14 % of those who accessed the survey and 48 % of those who started to answer it). The mean processing time was 13 min 26 s. Respondents represented a total of 36 different networks (see the list of represented networks in Appendix B.1.). 77 % of the respondents identified themselves as scientists, 7% as representatives of civil society, 5% as policy makers, while the remaining 11 % expressed that they had multiple backgrounds (selecting at least two of the three options of science, policy and civil society).

Quantitative data from the survey was analysed with the SPSS software, using descriptive statistics (frequencies, cross tabulations), while the open-ended questions were subjected to thematic content analysis. An independent equal variance *t*-test was carried out to analyse if survey results (individual responses) and interview results (interviewed networks' opinion) are significantly different concerning the potential roles to take in a NoN (Q4 in the survey and Q9 in the interviews, see also

below).

2.2. Semi-structured interviews

To identify the key characteristics of networks which are currently active at the SPI, and to better understand the motivations and barriers supporting or hindering their active participation, we used qualitative semi-structured interviews. The interview guide focused on 4 topics, the three first of which focused on our research questions: 1) the key characteristics of the networks including their objectives, governance structure and process, and funding model (Q1, Q3, Q4 Q5 in the guideline, answering research question no.1.), 2) the range of stakeholders they engage with, potential roles to take in a NoN, and the preferred means of communication and capacity building (Q2, Q9, Q11, Q12 in the guideline, answering research question no.2.), 3) the challenges faced and the gaps in knowledge and capacities (Q7 and Q10 in the interview guide, answering research question no.3.), and 4) expectations towards Eklipse and major connections with other networks (not analysed in this paper).

Existing networks, operating at European or regional level, were selected for the interview from a database compiled in a desk research (Eklipe Deliverable D5.1) and partly from information from forerunner projects (i.e. KNEU). The key principles of the selection process was 1) to contact those networks which are the most relevant and active in terms of science-policy interfacing for biodiversity and ecosystem services; and 2) to contact diverse networks in terms of involved actors and expertise (i.e. multiple scientific disciplines, policy and practice actors including the NGO and the business sector). A total of 22 interviews were conducted, and an additional 5 long questionnaires from the pilot phase were included in the analysis, resulting in 27 networks being represented during the qualitative phase of the research (see Appendix B.2. for the full list of interviewed networks).

Lead representatives of networks (i.e. the president, board members, communication or networking officer) were contacted to be interviewed. Seven interviews were face-to-face, while the rest were done via online communication. Written notes were prepared for all the interviews and were sent back to the interviewees for checking any errors or misunderstandings. All data was uploaded to the UNIPARK server to store them securely and anonymously. The length of the interviews varied between 30 min and 3 h, being 60−70 min on average. Interview notes were qualitatively analysed by thematic content analysis, while closed questions were analysed with simple descriptive statistics.

This mixed method approach did have its limitations. Firstly, the low response rate limited our choice of statistical methods, but the open questions included in the survey provided additional textual information which we could qualitatively analyse and compare with interview results. Secondly, asking respondents about their own or their network's potential contributions to a NoN proved to be a difficult question. In the survey the highest number of drop-outs were realized at this question, probably because the roles were not clear enough to make a solid selection. The interview situation provided more room for reflection but created another challenge: as interviewees responded on behalf of their networks, and as networks rely very much on the activity of their membership, the interviewed representative might have not been able to express commitment on behalf of its members. Finally, the fact that the majority of interviewees and survey respondents were recruited from fields directly related to biodiversity and ecosystem services research highlights the difficulties in engaging a wider range of potentially interested actors, as the relevance and added value of a science-policy interface for biodiversity might not be so evident to them. Despite our efforts, organizations having a strong citizen engagement element remained underrepresented, which makes it difficult to judge whether and how citizens (or their representative bodies) should be engaged in science-policy interactions.

3. Results

3.1. The major characteristics of networks active at the biodiversity science-policy-interface

The main functions and activities reported by the interviewed networks included knowledge creation and sharing with diverse audiences, as well as the provision of training to their members on knowledge generation, synthesis and dissemination. Bringing people and ideas together from science, policy and society, and strengthening the science-policy interface by working on policy-relevant research, were mentioned as key objectives by many, although more practical aspects of such boundary work (e.g. lobbying, directly influencing policy development, or providing funds or expertise to others to do so) were reported only by a few networks.

Diversity within the membership (i.e. engaging actors beyond science from policy, business or the social sphere, and often both individual and organizational members) was considered as a strength and was reported by many interviewees (Fig. 3/a). Nevertheless, in most of the interviewed networks academic partners dominated, which was also reflected by the fact that most networks identified themselves as scientific or academic. Many networks, including those not claiming to be academic, mentioned that they aimed to be multi- or transdisciplinary and saw this as their strengths. Only a few networks indicated that they centred around people from one specific discipline, more common was the engagement with people with different expertise and disciplinary backgrounds to create and share knowledge on critical issues. This indicates that networks acting at the biodiversity SPI were more problem-oriented than disciplinary-focused.

Governance and decision-making procedures exhibited a combination of top-down and bottom-up approaches, allowing the membership to decide on major strategic issues by means of voting or consensus, but centralizing operative decisions in administrative or executive bodies (Fig. 3/b). Networks with a large and geographically wide membership tended to provide a regionally balanced representation for their members (e.g. region-specific chapters or national representatives within the executive body), and to create committees to manage specific network functions along a lighter, more informal procedure. This heterogeneity suggests that creating a NoN with active participation of different networks might be a long and legally complicated procedure, because joining a NoN might require decisions to be taken by different bodies of a network.

Funding was a critical issue for many of the interviewed networks. Approximately half of them collected a membership fee from individual members or member organizations (Fig. 3/c). Some of the networks claimed that they faced problems with collecting membership fees, i.e. members often neglected to pay their fees and showed a relatively high fluctuation over time. Reasons for this may either be the limited financial capacities of members, or a more flexible networking strategy encouraging individuals to look for new networks to join after a certain period, but also the fact that benefits offered to members might not be perceived as being worth the membership fee. Diversifying the funding sources was mentioned as an important strategy to strengthen sustainability and adapt to changing conditions. As such, almost half of the networks ($n = 11$) had already been diversifying their revenue sources and therefore selected more than one funding source from the options listed.

3.2. Who could contribute to a more effective science-policy-interface and how

Both individual respondents and network representatives stated that effective science-policy interactions should include multiple actors, such as scientists with backgrounds in natural and social sciences, policy-makers from the national to the EU level or even broader, and representatives of civil society and the business sector. Individual citizens and

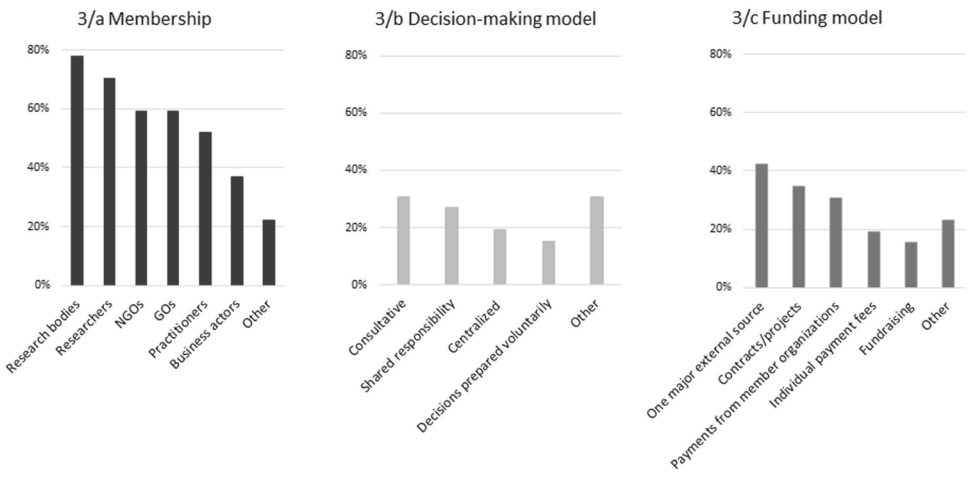

Fig. 3. Characterization of networks being active at the SPI.
Respondents could choose multiple options at each question. The *y* axis always shows which proportion of the respondents selected the given response option (100 %=total number of respondents (n)). Fig. 3/a indicates which types of actors were engaged in the interviewed networks as members (n = 27). Fig. 3/b indicates how decisions were predominantly taken in the interviewed networks, the 'other' category mainly referring to shared responsibility and mixed decision-making models across the different bodies of networks (n = 26). Fig. 3/c shows what were the dominant founding sources of networks, the category 'one major external source' referring to the presence of a key funding body (i.e. government or charity) (n = 26).

scientists from other disciplinary backgrounds were generally considered less important participants of the SPI. To identify the potential contribution of individuals and networks in such efforts, through the Eklipse Mechanism or other structured procedures with similar goals, respondents were asked to evaluate the capacity and interest they themselves or their networks could offer in terms of specific contributing roles, including the provision of thematic and methodological expertise, research tools and infrastructure, access to data and information, foresight, evaluation activities, think tank and knowledge hub activities, capacity building, communication, society and policy interaction, and management support (KNEU Team, 2014).

An independent *t*-test was used to compare individuals' and network representatives' responses, which proved significant difference between the two samples only for one variable: the provision of thematic expertise (t value was 2.07 at the decision rule 'reject H0 if t>1.665 (p = 0.05)'). Both types of respondents felt the most comfortable offering their thematic expertise as a support for science-policy interactions, but networks have significantly stronger capacities to do so than individuals. Results in overall (Fig. 4) reinforced that contributions are most probable for knowledge, data and expertise related tasks, while both networks and individuals seemed to lack capacities to provide management support. Some slight differences between potential contributions could also be observed, although not significant, i.e. individual experts might be easier to engage in evaluation, foresight and think tank activities, while existing networks could contribute to SPI work by granting access to their databases, tools and infrastructure, or by offering capacity building and communication services.

Engaging citizens in science-policy interfaces was a contested topic. Our respondents mostly suggested that individual citizens should be engaged in SPIs indirectly, through representative organizations, i.e. non-governmental or civil society organizations, while only few responses favoured direct public participation.

Respondents listed some additional stakeholder groups that should be involved in science-policy interactions. Farmers/land-users (including agriculture, fisheries and forestry) and business actors (industry and supply chain) were mentioned most frequently, followed by NGOs (especially those working with conservation), regional and local decision-makers, and other local stakeholders. Science-policy interactions were considered by some as multi-level processes, suggesting that actors from the local to the global level (e.g. UN and its institutions) might be relevant to invite, although creating space for meaningful engagement in a multilevel and multilingual context was perceived challenging. Language barriers, low level of motivation, differences in the dominant channels of communication, and lack of financial support were reported as potential barriers to active collaboration across countries. Establishing ad-hoc, thematic working groups which focused on policy issues of local or national relevance, and appointing national contact points to create a more active linkage across multilevel decision-making processes were two dominant strategies of networks to increase the level of engagement of their members.

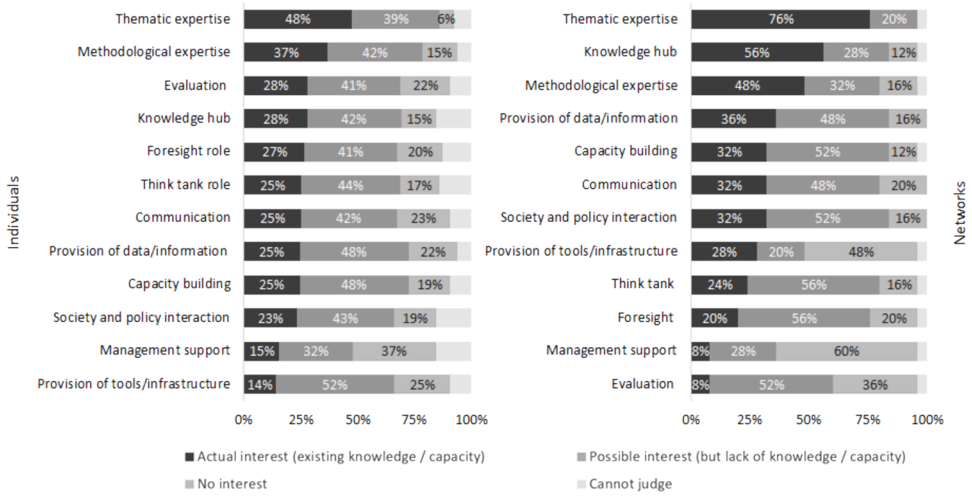

Fig. 4. Potential contributions of individuals and networks to SPI work, listed in decreasing order (valid number of responses is n = 62 for individuals, and n = 27 for networks).

3.3. Challenges and limitations faced when acting at the science-policy-interface

Key challenges identified by interviewees ranged from securing continuous funding over a longer time period, to actively engaging members in joint activities, and making a true and visible impact. Being flexible and adapting to change were recurring topics considered necessary to manage internal tensions and to *"convince the members to contribute more than minimum, to find new members"*. The networks with strong institutional membership providing secure funding (e.g. governments, donors) were able to apply more nuanced and creative approaches to engage diverse stakeholders (e.g. citizens or actors at local and national level) in creating policy or societal impact at smaller scales.

While some networks reported that their current situation - especially the lack of financial resources - limited their capacity to engage in SPI activities, others considered that being more active in the science-policy sphere could help them overcome difficulties within the membership or could increase the impact of the network. Making a true impact on policy was the aspiration of many networks but was only reached by a few, and their success always depended on external (f) actors: *"It is difficult to transform scientific results to something with societal value, like policy. To make this into policy you need the government involved, which is not necessarily easy or always feasible."*

A major knowledge gap that prevented SPI activities, according to both survey respondents and interviewees, was the lack of understanding of scientific actors on how the policy process functioned, and vice versa, the lack of experience of policy actors on how robust scientific results were generated. This was closely interlinked with capacity gaps in knowledge (co-)creation, networking and communication. Collaborating at the SPI requires specific skills both from the scientist and the decision maker, including, among others, collaboration across disciplines and beyond science, working in diverse teams, facilitating open dialogues, or clear communication for various audiences. As some study participants highlighted, targeted communication and the effective use of various communication channels are not sufficient for a successful science-policy interface; *"a common language between actors"* is needed to increase the clarity of the final messages.

Existing institutional structures also often acted as barriers for science-policy interactions. Many survey respondents shared their concern of lack of time and funding to cover their SPI-related work. More importantly, if it did not culminate in a peer reviewed paper, science-policy interfacing was not perceived as being acknowledged by most academic institutions or universities: *"At the moment, researchers get paid by the number of scientific publications and not for their science-policy-society interface contributions"*. The lack of institutional incentives to participate in an SPI can be overcome with a strong personal motivation and willingness to participate, until internal SPI structures and processes guarantee equal opportunity for experts to participate and a valid mandate and a general acceptance towards participating researchers from the policy side. However, as one of our interviewees acknowledged, having direct access (i.e. personal contact) to policy makers is sometimes more impactful than any well-structured and formalized science-policy interface.

4. Discussion

Most of our study participants recognised the growing need for an institutionalized, EU-level SPI on biodiversity and ecosystem services. This need was partly based on the perception that policy processes often fail to take into consideration the best available scientific knowledge, therefore an SPI which improves the knowledge base for policy decisions may contribute to better policy outcomes. Inviting existing networks to science-policy interactions seems to be beneficial from at least three angles: concerning the processes (i.e. by dividing work among available experts), the outcomes (i.e. by using the best available knowledge), and the participating networks themselves (i.e. by increasing the policy relevance of their work). However, to successfully engage networks in a more formalized collaboration, a 'network-of-networks' must be able to motivate participating networks to actively take part in joint actions, and must help them match the gaps in knowledge and capacities which hinder them doing so. In this section we highlight three potential ways to increase motivation, before identifying capacity development options to improve networks' ability to take part in SPI activities.

4.1. Motivation of networks to participate in a network-of-networks

Our study demonstrates that while there is an interest in individual experts and networks to actively engage more with the SPI, contributions to a potential network-of-networks which could facilitate participation at the SPI remain rather hypothetical (see Fig. 4). Building a robust and viable NoN is only possible if the member networks are motivated to join and collaborate. Keeping up the motivation of networks to participate is best guaranteed if the primary objectives of member networks are aligned with and mutually reinforcing the overall aims of the NoN. Based on the survey and interview results, three target areas were identified where engaging in a NoN can strengthen individual networks' goals and create benefits for them.

First, we observed that most networks active at the SPI intend to position themselves by defining their own thematic areas and unique added value related to biodiversity, ecosystem services, and relevant fields. However, as the NoN engages with multiple networks, there are overlaps in interests and focal topics which might be seen as a factor that increases competition among NoN members. We think that such partly overlapping expertise across the networks can be considered as redundancy contributing to the robustness of the NoN (Radicchi and Bianconi, 2017; Reis et al., 2014), and therefore can be beneficial for the member networks as well as for the knowledge requester. Redundancy within the NoN in terms of overlapping expertise might reduce the intensity of work required by an individual network, can guarantee a reliable and continuous access to relevant expertise, knowledge and data, and can create synergistic outcomes and more robust solutions.

Secondly, most existing networks look for opportunities to link across different geographical and governance scales and upscale their lessons learnt at the local or regional level. Cross-scale interaction is crucial to create a dialogue between global problem framings and their local manifestations, can help find workable policy solutions (Hoppe, 2010; Balvanera et al., 2017), and can contribute to the legitimacy and effectiveness of the SPI. Science-policy interactions are usually considered effective by stakeholders only if their concerns are addressed across multiple scales (Weichselgartner and Kasperson, 2010). If, for example, local level actors perceive that an SPI at a global scale has no relevance to their (local) concerns, the global SPI efforts might suffer huge implementation gaps due to lack of motivation of local actors. At the same time, local level science-policy interactions are better positioned, and potentially more influential via global/national/regional actors, when embedded in higher level SPI activities. This reflects our previous findings regarding societal engagement on European scale: special emphasis should be on both the commitment and embeddedness into national contexts and the added value of approaching them together on the multi-national level (Varumo et al., 2020). Consequently, scaling up and scaling down are both relevant issues for any SPIs, and can be a targeted activity of a network-of-networks.

Thirdly, we identified knowledge creation and sharing as one of the key motivational aspects of the network participants. Most scientific communities believe in increasing their impact and legitimacy through improved communication and dissemination, which is still perceived as one of the major gaps in knowledge and capacity. This inner motivation of individual researchers and networks for continuous improvement could be taken up and met through capacity development activities by the NoN.

4.2. Matching gaps of capacities at individual and network level

Targeted capacity and knowledge building activities can help networks to improve their knowledge base, strengthen collaborative relationships, and make their functioning more effective, which is also crucial for SPI activities (Matsumoto et al., 2020). Table 1 links the major challenges identified in this study (section 3.3) to the capacity dimensions highlighted in the literature (Kuhlicke et al., 2011; Gupta et al., 2010) by grouping the challenges along two criteria: whether they refer to gaps in capacity or knowledge, and whether they arise from an increased need for specific (inter)personal skills or from structural conditions.

Based on Table 1, we suggest three different strategies a NoN can apply to help its members fill their major capacity and knowledge gaps. Capacity and knowledge gaps concerning skills-related conditions can be filled via participatory capacity development approaches, focusing both at individual and organizational capacities. Interactive formats, such as training courses, workshops, matchmaking events and pilot demonstrations, were listed by our study respondents as effective ways of developing personal skills and knowledge. Web-based tools, such as webinars or online knowledge platforms, were listed by study respondents less frequently, suggesting that developing (inter-)personal skills and capacities is more effective in direct, face-to-face events.

Knowledge gaps related to structural conditions can be targeted by creating inter- and transdisciplinary learning environments, where researchers and policy decision makers actively engaging with an SPI can meet and learn from each other in order to change organizational cultures and processes. One possible format, suggested by our study participants, was the provision of funds to establish joint teams of scientists and policy-makers (and the general public) that can work in an action-oriented way.

Capacity gaps related to structural conditions are beyond the horizon of individual networks as they indicate the need to change the wider institutional field. However, a NoN can fight for institutional change via lobbying and advocacy, and push for an interventionist approach of capacity development, which focuses on the policy dimensions, as well as on the legal, regulatory and institutional conditions of SPI-related work (Kuhlicke et al., 2011). Examples of such an interventionist approach could be lobbying for the institutional recognition of researchers' efforts at the SPI, e.g. by advancing their careers or granting a certain percentage of their working time to be used for SPI oriented work.

Table 1
Capacity and knowledge gaps of interviewed networks paired with potential strategies for capacity development.

Skills-related conditions	**Capacity gaps** Communication problems with stakeholders and lack of familiarity with the use of various media channels, difficult networking across sectors and geographical regions	**Knowledge gaps** Difficulties of multi- and interdisciplinary work, lack of common language across different disciplines, difficulties of navigating in the policy cycle and legal structures
	Linked capacity dimensions Motivational capacities & Social networking skills	**Linked capacity dimensions** Knowledge integration and learning capacities & Social networking skills
	Potential capacity development strategy Participatory capacity development activities, incl. face-to-face and online trainings, workshops, pilot demonstrations etc. – focus on both individual and organizational capacities	
Structural conditions	**Capacity gaps** Lack of human and financial resources as well as incentive structures for scientists and experts	**Knowledge gaps** Lack of data on biodiversity and ecosystem services, lack of integration of ecological knowledge with economics and social sciences, lack of handling uncertainty
	Linked capacity dimensions Financial and human resources & Governance and leadership capacities	**Linked capacity dimensions** Governance and leadership capacities & Knowledge integration and learning capacities
	Potential capacity development strategy Advocacy work and interventionist capacity building – focus on the institutional context	**Potential capacity development strategy** Open learning environments for inter-and transdisciplinary interactions – focus on organizational capacities

5. Conclusion

This study aimed to assess how a NoN can help existing networks to act more effectively at the boundary of science and policy. We analysed the major characteristics of networks being active in biodiversity SPIs, the potential roles different actors (networks and individuals) can take at the SPI, and the major challenges faced by networks and individuals when acting at the SPI. We found that existing networks are diverse in terms of their membership, internal structures, processes and funding models. This diversity provides a twofold strength when networks join their forces in a NoN: they are different enough to cover diverse areas of expertise and provide the best available information, and they overlap enough to divide tasks and share responsibility when resources are scarce. Although our study focused on the field of biodiversity, examples from the forestry or agricultural sectors reinforce that SPI processes and network characteristics are not considerably different (Päivinen and Käär, 2018; Šūmane et al., 2021), therefore key findings might be applicable at a wider scale.

Results showed that a network-of-networks approach to SPIs can help science to meet policy demands more effectively, and to provide more robust outputs to evidence-based policy decisions. However, we also realized a divergence between the willingness and the actual capacities of actors to contribute to a network-of-networks style SPI, which highlights that contributions to boundary work are highly dependent on individual and organizational capacities. We argue that capacity and knowledge gaps hinder both networks and individual actors to effectively participate in SPI activities, whether organized in a NoN or in any other setup. While regular capacity building and knowledge sharing activities can be utilized to improve skills and soft conditions, matching capacity gaps that emerge due to institutional constraints needs an interventionist approach. We suggest capacity development and advocacy work being an integral part of the NoN to help its members overcome the most critical challenges that hinder their participation in boundary work.

Author statements

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

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